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Design and Analysis of Knockout Drum

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ABSTRACT :

Compressor suction knockout drum is one of type of pressure vessel and is used to remove liquid droplets carryover in gases to protect the downstream equipment. The knockout drum helps in improving performance of the compressor and by using this component in the compressor, corrosion of the compressor reduces. This paper deals with design, simulation, and fatigue life of compressor suction knockout drum. First the model is prepared using CATIA V5 software. Later, this model is used in ANSYS software to perform Static analysis, Thermal analysis.

Keywords: Knockout drum, Modelling, Analysis, probabilistic technique, simulation

1. Introduction

A Compression Suction Knockout Drum (CSKD) is one of the types of pressure vessel used as a real time component in many industries, such as chemical, petroleum, gas, oil, and oil refining industries. This is used to remove liquid droplet carrying over in gases through a mist pad which is fastened overhead the inlet valve/nozzle and beneath to the dish head. The feed to a vapour-liquid separator may also be a liquid that is being partially or totally flashed into vapour and liquid as it enters the separator [1]. Thus protect the downstream equipment, usually a reciprocating or centrifugal compressor. Most compressor suction knockout drums are arranged vertically. Gravity causes the liquid to settle to the bottom of the vessel, where it is withdrawn. The vapour travels upward at a design velocity which minimizes the entrainment (the process of making something part) of any liquid droplets in the vapour as it exits from the top of the vessel [2].

The most common forms of compression knockout drum in many technological applications are those subjected to internal pressure and external loads. Analytical & Numerical solutions of internal forces by cylindrical pressure vessel with semi elliptical head [3]. Stress analysis of cylindrical vessel with changeable head geometry ie: semi elliptical, hemispherical is analyzed if required to obtain contented outcomes-based application [4]. Elliptical head pressure vessel non radial & offset connections have non uniform distribution of stresses interaction region which decreases with the maximum effective stresses, as angle α increases for non-center connections [5]. The application of adequate stress-relieving reinforcements is one of the challenges with compression knockout drum design. To ensure the safety of the pressure vessel, many types of connections are used. These connections include welded pad reinforcement, self-reinforced nozzles, and internally protruded connectors. A variety of studies have been conducted to examine pressure vessel safety under various loading situations due to the relevance of pressure vessels in engineering applications and the potential of safety concerns in the case of an accidents. There are a variety of codes that detail the rules and regulations that must be followed to ensure that equipment is constructed safely [6].

The performance of the suction knockout drum is analyzed in this study using simulation software “ANSYS” and the results are compared through analytical methods. The simulation model considers various operating conditions such as pressure, fluid properties and stress analysis to stimulate the loading conditions. These loading conditions effects the operating conditions on the separation efficiency and pressure drop in the drum. The results attained through the analysis furnish valuable insights of the performance of the compression knockout drum, which can be used to optimize its design and as well as its operation [8]. Additionally, the results can be used to enhance the overall efficiency, safety and as well the life time of compression knockout drum.

2. Literature Review

[1] Donald Mackenzie (Design by Analysis of Ductile Failure and Buckling in Tori-spherical Pressure Vessel Heads) (July to September -2008) The paper deals with study of torispherical pressure vessel head. This type of vessel exhibits complex elastic-plastic deformation and buckling behaviour under static pressure. Author has assessed both of these behaviour modes while specifying the allowable static load. By the direct route in EN code inelastic analysis is used. Plastic collapse or gross plastic deformation loads are evaluated for two sample torispherical heads by 2D and 3D FEA based on an elastic material model. Small and large deformation effects are considered in 2D analysis and the effect of geometry and load are considered in 3D analysis.

[2] Chaaba (Plastic Collapse Assessment Of Thick Vessels under Internal Pressure According to Various Hardening Rules) (October- 2010) This paper aims to deal with plastic collapse assessment for thick vessels under internal pressure, thick tubes in plane strain conditions, and thick spheres, taking into consideration various strain hardening effects and large deformation aspect. In the framework of von mises' criterion, strain hardening manifestation is described by various rules such as isotropic or kinematic laws.

[3] R.C. Carbonari (Design of Pressure Vessels using Shape Optimization: An Integrated Approach) (May-2011) The paper discusses shape optimization of axisymmetric pressure vessel considering an integrated approach in which entire pressure vessel model is used in conjunction with a multi-objective function that aims to minimize the von-mises mechanical stress from nozzle to head. The different shapes from usual one are obtained. Even though such different shapes may not be profitable considering present manufacturing processes, they may competitive for future manufacturing technologies and contribute to better understanding of the actual influence of shape in the behavior of pressure vessels.

[4] Bandarupalli Praneeth, T.B.S.Rao (Finite Element Analysis of Pressure Vessel and Piping Design) (2012) Features of multilayered high pressure vessels, their advantages overmonoblock vessels are discussed in this paper. Various parameters ofsolid pressure vessel aredesigned and checked according to the principles specified in American Society of Mechanical Engineers (ASME) Section VII Division 1. The stresses developed in solid wall pressure vessel and multilayer pressure vessel is analyzed by using ANSYS.

[5] Vishal V. saidpatil, Arun Thakare (Design & Weight Optimization of Pressure Vessel Due to Thickness using Finite Element Analysis) (June2014) The aim ofthis paper to carry out detailed design & analysis of Pressure vesselused in boiler for optimum thickness, temperature distribution and dynamic behavior using Finite element analysis software. The model is analyzed in FE solver. Paper involves design of a cylindrical pressure vessel to sustain 5 bar pressure and determine the wall thickness required for the vessel to limit the maximum shear stress. Geometrical and finite element model of Pressure vessel is created using CAD CAE tools. Geometrical model is created on CATIA V5R19 and finite element modeling is done using Hypermesh.

[6] Jayashri Wagh (Analysis of Effects of Quench Nozzle on Pressure Vessel Design – A Review) (June-2015) This paper gives the effects of quench nozzle on the pressure vessel design.Author studied and analysed the effect of nozzle location on pressure and temperature. Thesenozzle if present on peak of dish end do not disturb the symmetry of the vessel. Sometimes process requirement dictate that some quench nozzles to be placed on the periphery of the pressure vessel and need to analyzed in FEA for stress attributes of the vessel.

[7] Patel Nikunj, Ashwin Bhabhor (Design and Analytical Calculation of Reactor Pressure Vessel) (May-2019) Author evaluated the design of reactor pressure vessel designed by"New bluemoon engineers" and done new design of some major parts. The design is compared through experimental and analytical base modeling and thermal analysis by using advanced CAE tools. So it gives the best design which is feasible for reactor pressure vessel.This paper gives some of the important information, knowledge and analytical calculation and comparison of existing and new design of vessel to empower the basic fundamentals to carryout work. The pressure vessel is of elliptical dished end and it is designed by considering three major design parameters as design pressure, allowable stress and corrosion allowance.

Summary of literature:

The literature reviewed includes study of stresses, non –linear analysis, fatigue analysis, thermal analysis. Major focus of the researchers is on stress analysis due to pressuregenerated in the vessel. Hence it is found that none of the researcher focused on theoptimization for support location and nozzle location. It is essential to study the effect of nozzle location and support location due to which stresses generated in the shell. The locationof support affects the stress concentration. Location of the nozzle will help to reduce the concentration of the stress at particular location. Hence this gap causes to focus on the area optimization of structure by nozzle location and support location.

3. Methodology

- All needed dimensions for components like flanges, pipes, shell, are extracted from pressure vessel data sheets and standard data like ANSI & ASME.
- 3D modeling of components is done using CATIA V5 and these individual parts are assembled/ integrated to entire the assembly.
- Stress analysis of pressure vessel using analytical equations.
- The pressure vessel analysis is simulated using ANSYS software and the results are observed.
- Comparison of analytical results with ANSYS results.

4. Design of Knock out Drum

The design of compression suction knockout drum (CSKD) is done with the design parameters, all the parts were modeled in CATIA V5 using the same approach. Design criteria and design standards are considered according to pressure vessel data sheets. All the parts were modeled using CATIA V5 by following the same procedure with changes in design parameters. The design parameters with design standards are considered with pressure vessel data sheets.

2D drawings are drawn then converted to 3D drawings using Pad, Pocket, Revolve features in CATIA V5. The parts which are made in 3D are made into an assembly. All the parts must be carefully placed as per assembly standards viz Lengths and Angles.

The required data is collected from Data sheets

The Overall length of the Pressure vessel is 9010.65 mm

Inner diameter of shell is 1828.8 mm

Tan to Tan length is 5943.6 mm

Inner Diameter of shell is 1828.8 mm

Shell thickness is 16 mm

Head thickness is 16 mm

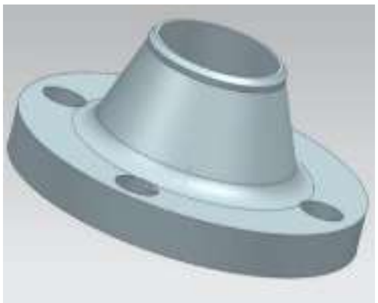


Fig 4.1 Nozzle

Fig 4.2 Dish

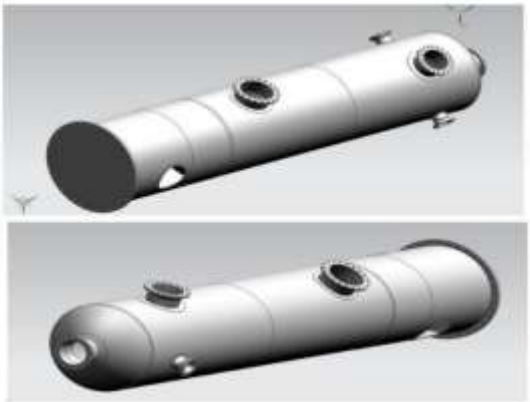
Fig 4.3 RF pad

Fig 4.4 Flange

Fig 4.5 Shell

Fig 4.6 Flange

Fig 4.7 Assembly of Knockout drum



4. Formation of a mesh

Ansys Workbench is used to solve a wide variety of mechanical problems like static, dynamic, structural, heat transfer etc., To analyze the model, initially the assembly which was modelled in CATIA software is converted to IGES format. So that ANSYS software will be able to read the geometry of the model. The geometry was imported to the ANSYS software. In ANSYS the meshing is used to divide the model into 55541 tetrahedral elements of having 114371 nodes. The material taken is SA516Gr.60N and pressure is taken as 0.345MPa.

Property	Value
Density	7850 kg/m^3
Young’s Modulus	2 x 10^5
Poisson’s Ratio	0.29
Bulk Modulus	1.5873 x10^11
Shear Modulus	7.7519 x10^10
Tensile Yield Strength	415 MPa
Tensile Ultimate Strength	540MPa

4. Analysis of Compression Suction Knockout Drum

The analysis is done for two models one is without nozzles and the other is with nozzles. Analysis without nozzles is done for comparing the output results with the analytical results. The model with nozzles is the one to be used in real life

4.1 Analysis of Assembly without Nozzles

The model in Catia is saved in a IGES format and done meshing in ANSYS. The model meshing results 10691 tetrahedral elements of having 22883 elements. The inputs of pressure, Standard earth gravity, determining the fixed end etc. are given and the outputs of static stress, deformation, etc. are taken by solving them.

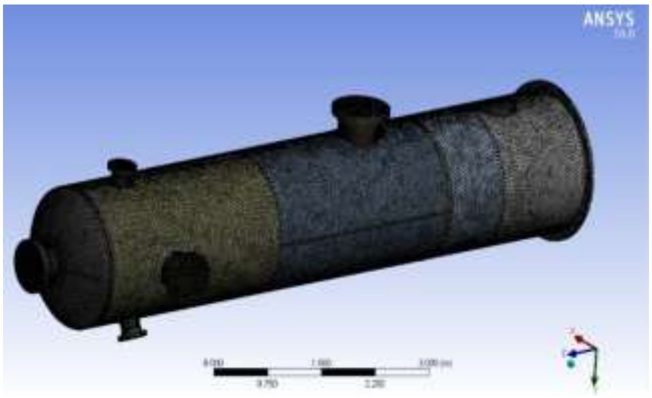


Fig 4.1 Geometry model of Pressure vessel

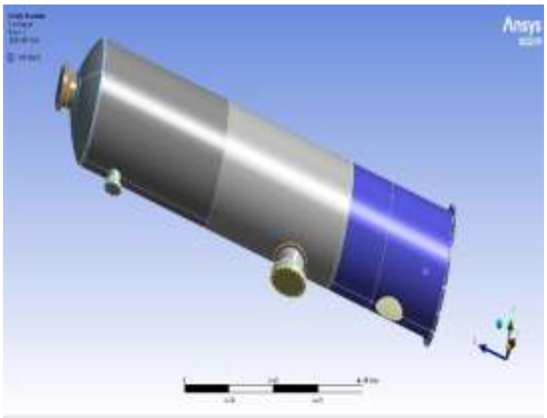


Fig 4.2 Standard Earth Gravity

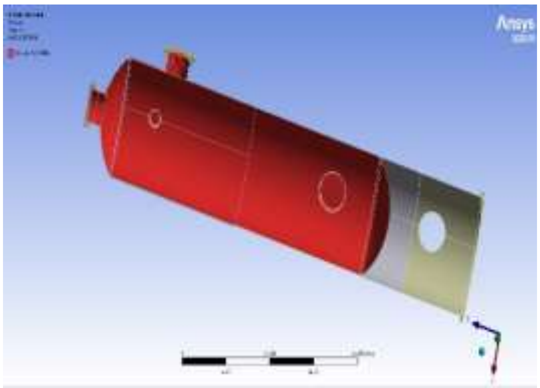


Fig 4.3 Fixed Support

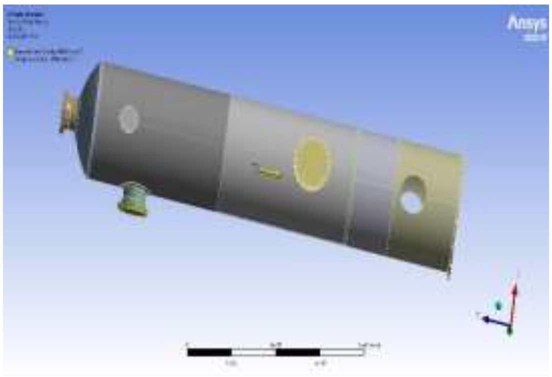


Fig 4.4 Pressure

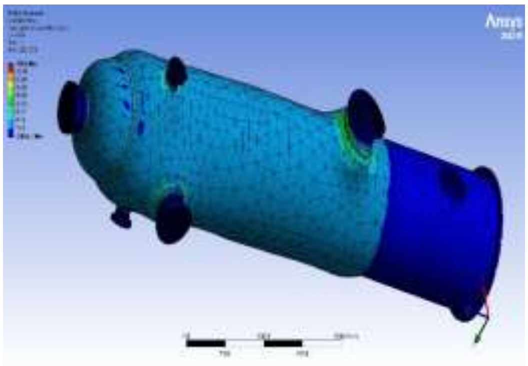


Fig 4.6 Total Deformation

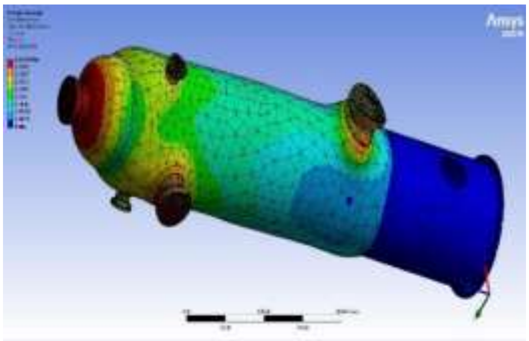


Fig 4.5 Equivalent stress

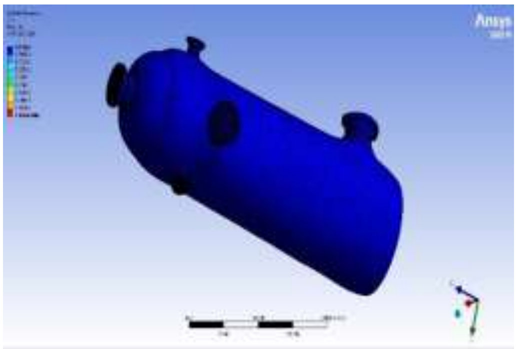
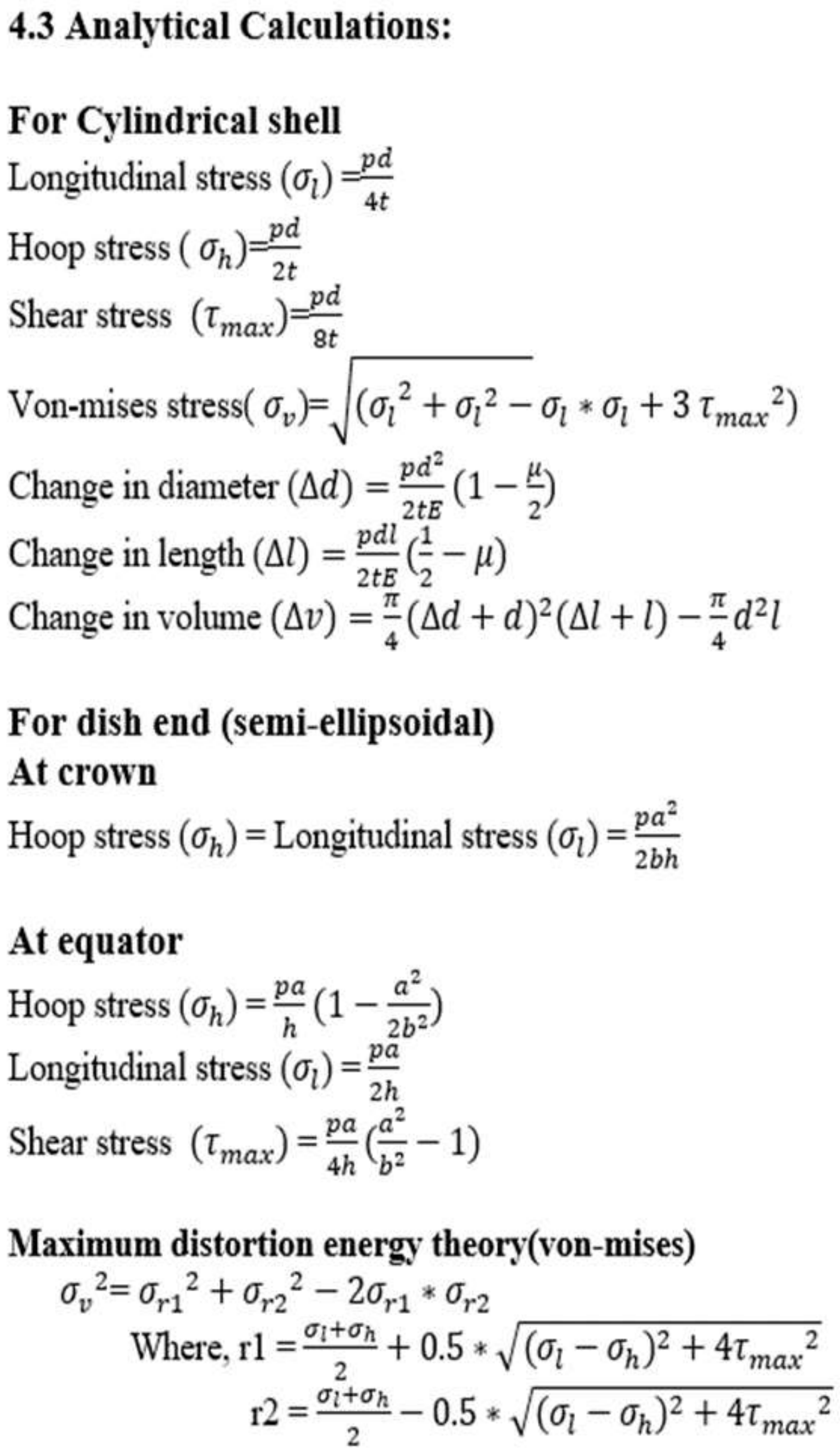


Fig 4.7 Fatigue Life

When pressure is applied to overall faces of the Pressure vessel, the total deformation is shown in the diagram above; the red area represents the most deformation, while the blue region represents the least deformation.



4.3 Analytical Calculations:

For Cylindrical shell

Longitudinal stress $(\sigma_l) = \frac{pd}{4t}$

Hoop stress $(\sigma_h) = \frac{pd}{2t}$

Shear stress $(\tau_{max}) = \frac{pd}{8t}$

Von-mises stress$(\sigma_v) = \sqrt{(\sigma_l{}^2 + \sigma_l{}^2 - \sigma_l * \sigma_l + 3\,\tau_{max}{}^2)}$

Change in diameter $(\Delta d) = \frac{pd^2}{2tE}(1 - \frac{\mu}{2})$

Change in length $(\Delta l) = \frac{pdl}{2tE}(\frac{1}{2} - \mu)$

Change in volume $(\Delta v) = \frac{\pi}{4}(\Delta d + d)^2(\Delta l + l) - \frac{\pi}{4}d^2 l$

For dish end (semi-ellipsoidal)

At crown

Hoop stress (σ_h) = Longitudinal stress $(\sigma_l) = \frac{pa^2}{2bh}$

At equator

Hoop stress $(\sigma_h) = \frac{pa}{h}(1 - \frac{a^2}{2b^2})$

Longitudinal stress $(\sigma_l) = \frac{pa}{2h}$

Shear stress $(\tau_{max}) = \frac{pa}{4h}(\frac{a^2}{b^2} - 1)$

Maximum distortion energy theory(von-mises)

$$\sigma_v{}^2 = \sigma_{r1}{}^2 + \sigma_{r2}{}^2 - 2\sigma_{r1} * \sigma_{r2}$$

Where, $r1 = \frac{\sigma_l + \sigma_h}{2} + 0.5 * \sqrt{(\sigma_l - \sigma_h)^2 + 4\tau_{max}{}^2}$

$r2 = \frac{\sigma_l + \sigma_h}{2} - 0.5 * \sqrt{(\sigma_l - \sigma_h)^2 + 4\tau_{max}{}^2}$

5. Conclusion:

The result of this study can be summarized as follows: (1) Various parameters of pressure vessel such as the internal design pressure, the design temperature, and the component dimension are designed in accordance with ASME boiler and pressure vessel. (2) The evaluation junction area of pressure vessel has been performed using FEA and methodology of ASME and carried out under the prescribed specific load conditions. (3) The stress equivalent and stress classification lines of pressure vessel components are lesser than the allowable stress of the material. (4) The analysis results for the normal operating condition satisfied allowable limits. Therefore, current design of the blind flange, shell flange, and eye bolt has enough strength under the design load conditions.

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